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Wayfinding in Large-Scale Virtual Worlds

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ABSTRACT

The spatial nature of large-scale virtual worlds introduces wayfinding problems which are often overlooked in the design process. In order to design and build useful virtual worlds in which real work can take place, these issues must be addressed. The research described here is a study of human wayfinding in virtual worlds and how real world solutions can be applied to virtual world design. The objective of this work is to develop design principles which will lead to a design methodology for virtual worlds in which wayfinding problems are alleviated.

INTRODUCTION

Problems associated with wayfinding have been encountered in every virtual environment laboratory in every large-scale virtual world. These problems may manifest themselves in a number of ways depending on the task being performed. Virtual world navigators may wander aimlessly when attempting to find a place for the first time. They may then have difficulty relocating places recently visited. They are often unable to grasp the overall topological structure of the space. Any time an environment encompasses more space than can possibly be viewed from a single vantage point, these problems will occur.

The objective of this dissertation research is to develop design principles which can be incorporated into a methodology for the design of wayfinding augmentations to virtual worlds which will facilitate skilled searching and exploratory behaviors in novice users. Similarities between virtual and physical space make the application of environmental design principles to virtual world design possible.

Wayfinding Tasks

Wayfinding tasks are classified into three primary categories:

1. *Naïve search*: Any searching task in which the navigator has no a priori knowledge of the whereabouts of the target in question. A naïve search implies that an exhaustive search is to be performed.
2. *Primed search*: Any searching task in which the navigator knows the location of the target. The search is non-exhaustive.
3. *Exploration*: Any wayfinding task in which there is no target.

The classifications of wayfinding tasks are mutually exclusive. However, they are often compounded into sequences. In cases where the navigator has general knowledge of the target's position without enough precision to find it directly, a primed search is performed to the target's general proximity followed by a naïve search within that area.

Although purely naïve searches are rare in the real world, in virtual worlds, spatial naïvete is common in first-time explorers of a space; even by the world builder. A scientist visualizing data sets computed off-line may have no preconceived idea as to the shape or organization of the data. Therefore, wayfinding assistance requires support for both exhaustive and directed searches and must facilitate topological knowledge acquisition.

Spatial Knowledge

Wayfinding tasks in general require that the navigator be able to conceptualize the space as a whole. This is analogous to what Thorndyke [1] refers to as *survey knowledge*.

Survey knowledge represents configurational or topological information. Object locations and inter-object distances are encoded in terms of a geocentric, fixed, frame of reference. Survey knowledge is map-like in nature. Accordingly, it can be acquired directly from map use. However, survey knowledge acquired from a map tends to be orientation-specific. Prolonged exposure to navigating an environment directly results in survey knowledge which tends to be orientation-independent.

The resulting inflexibility of spatial knowledge acquired from maps led Levine [3] to study what effect this phenomenon has on map design. He found that in order to facilitate efficient map use, the map must be congruent with the environment it represents. This is illustrated in the *forward-up equivalence* principle which states that the upward direction on a map (assuming it is mounted perpendicular to the floor) must always show what is in front of the viewer.

Survey knowledge is hierarchical in nature [2]. Rather than encode the absolute positions and directions to every place encountered, fewer large, general, logically selected places (e.g. Washington, D.C.) are encoded with subnetworks of smaller, more specific places (e.g. The White House) being defined within each.

Environmental Design

Based on what is known about spatial knowledge and its role in wayfinding tasks, environmental designers have concerned themselves with developing a design methodology focussed on environmental organization and map use. Lynch [4] suggests that urban elements such as paths, landmarks, and districts be used to divide the environment into smaller, clearly connected, more manageable pieces. These pieces can then be directly encoded into a hierarchy of spatial knowledge. Lynch also notes the importance of frequent directional cues to orientation maintenance.

Passini [5] expands on these ideas applying them to architectural design. A space should have a basic organizational principle behind it. For example, Manhattan's streets are organized in a grid. We use this information directly to structure spatial knowledge. Most importantly, a space must have in it a number of "places" which are easily discernible to any wayfinder. A "place" is most simply defined as a distinct, recognizable location or region of a larger space. Passini also notes that if a map is to be used, it should show the organizational principle of the space as well as the design elements described by Lynch. The observer's position must always be shown and Levine's forward-up principle must be adhered to.

PROPOSED WORK

Previously, a number of navigation aids were implemented and tested as to their effect on subjects' ability to perform wayfinding tasks in virtual worlds [6]. However, although the earlier study addressed the fundamental issues of wayfinding, it did not culminate in a set of generalizable conclusions founded on scientific research. Rather, it presented a number of alternative cues and tools which were shown to improve subjects' performance. The objective of this body of research is to expand on earlier work by examining what environmental information is necessary for wayfinding tasks and to provide generalizable principles as to how this information can be supplied.

An optimal exhaustive search requires that the navigator traverse the entire space once (in the worst case). To facilitate this, there must be a method of organizing the space to eliminate multiple passes or skipping entire areas. A primed search, on the other hand, requires only that the navigator know a path to the target. If movement is unrestricted (as it often is in virtual worlds), the navigator need only know the direction and distance to the target. Minimal configurational knowledge is required relating the navigator's present position to the target's position. Lastly, exploration is the basic task of spatial comprehension. Its objective is to develop survey knowledge. Maps can be used and, similarly to naïve searches, the space should be explicitly organized.

These requirements lead to the conclusion that survey knowledge is the key to successful wayfinding in any environment. Therefore, based on the literature previously introduced, a set of design principles is presented for wayfinding augmentations to virtual worlds which will facilitate survey knowledge acquisition.

Organizational principles are meant to provide the necessary structure by which an observer can mentally organize the environment into a spatial hierarchy capable of supporting wayfinding tasks. The basic principles are:

1. Divide the large-scale world into distinct small parts, preserving a sense of "place".
2. Organize the small parts under a simple organizational principle.
3. Provide frequent directional cues.

The importance of maps to spatial knowledge acquisition cannot be overlooked. Ideally, this knowledge should be flexible, as if the observer had obtained it from direct experience. Therefore, the design principles below are intended to present spatial information in such a way as to produce a flexible, orientation-independent representation of the environment. The basic principles of map design are:

1. Show all organizational elements (paths, landmarks, districts, etc.) and the organizational principle.
2. Always show the observer's position.
3. Orient the map with respect to the observer such that the forward-up equivalence principle is accommodated.

An experiment will be conducted to evaluate the effectiveness of these principles on wayfinding behavior. Each subject will be exposed to four treatments. The first is the control treatment in which no wayfinding augmentations are added to the environment. There is a treatment for map usage, one for environmental organization, and one including both. Within each treatment, the subject will perform a naïve search, a primed search, and an exploratory task. All trials will be videotaped. During task execution, subjects will verbalize their spatial problem solving strategies. Execution time durations will be recorded as well as the subjects' position and orientation throughout the trial. At the conclusion of each trial, subjects will draw a sketch map of the environment to the lowest level of detail possible. We expect that task performance times will be significantly higher for the control treatment as compared to the other treatments. Furthermore, the verbal protocol analysis and map sketching exercise will show how the environment is mentally organized and consequently, why performance times differed.

CONCLUSION

Environmental design principles based on spatial orientation theory can be applied to virtual world design to build worlds in which wayfinding problems are minimized.

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